

We Claim:

1.. A catalytic vapor phase oxidation process, comprising :

(A) providing an oxidation reactor comprising a plurality of contact

5 tubes disposed in a reactor shell, the inside of the reactor shell being divided into at least first and second heat transfer zones through each of which a heat transfer medium passes; each of said contact tubes containing at least two sequentially disposed oxidation catalysts, said at least two oxidation catalysts being jointly capable of effecting the oxidation of a reactive hydrocarbon to a 10 product gas comprising (meth)acrylic acid, a first oxidation catalyst in said sequence being capable of effecting the oxidation of a reactive hydrocarbon to (meth)acrolein and being substantially located in that portion of each contact tube in contact with the first heat transfer zone, a second oxidation catalyst in said sequence being capable of effecting the oxidation of (meth)acrolein to 15 (meth)acrylic acid and being substantially located in that portion of each contact tube in contact with the second heat transfer zone; said contact tubes containing said at least two oxidation catalysts being packed with said at least two oxidation catalysts in such a manner so as to provide a peak-to-salt temperature sensitivity of not more than 9°C; and

20 (B) feeding a reactant composition comprising

(i) at least one reactive hydrocarbon, and

(ii) oxygen

into said oxidation reactor, at a reactive hydrocarbon space velocity of from 135 hr⁻¹ to 300 hr⁻¹, to contact said reactant composition with said at least two 25 oxidation catalysts to form a product gas comprising (meth)acrylic acid;

wherein, when said portion of each contact tube in contact with the first heat transfer zone comprises a plurality of sequentially disposed reaction zones, the temperature differential, $T_{SR1} - T_{IP1}$, between the temperature of each subsequent reaction zone, T_{SR1} , and the temperature of its immediately 30 preceding reaction zone, T_{IP1} , is less than +5°C;

wherein, when said portion of each contact tube in contact with the

second heat transfer zone comprises a plurality of sequentially disposed reaction zones, the temperature differential, $T_{SR2} - T_{IP2}$, between the temperature of each subsequent reaction zone, T_{SR2} , and the temperature of its immediately preceding reaction zone, T_{IP2} , is less than $+5^{\circ}\text{C}$.

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2. A catalytic vapor phase oxidation process, comprising:

(A) providing a first oxidation reactor comprising a plurality of contact tubes disposed in a reactor shell, the inside of the reactor shell being divided into at least a first heat transfer zone through each of which a heat transfer medium passes; each of said contact tubes containing at least one first oxidation catalyst, said at least one first oxidation catalyst being capable of effecting the oxidation of a first reactive hydrocarbon and oxygen to a first product gas comprising at least one second reactive hydrocarbon and oxygen, said contact tubes containing at least one first oxidation catalyst being packed in such a manner so as to provide a peak-to-salt temperature sensitivity of not more than 9°C ;

(B) feeding said first reactant composition comprising

- (i) at least one first reactive hydrocarbon, and
- (ii) oxygen

into said first oxidation reactor, at a first reactive hydrocarbon space velocity of from 135 hr^{-1} to 300 hr^{-1} , to contact said first reactant composition with at least one first oxidation catalyst to form a first product gas comprising at least one second reactive hydrocarbon and oxygen;

wherein, when each said contact tube of said first oxidation reactor comprises a plurality of sequentially disposed reaction zones, the temperature differential, $T_{SR1} - T_{IP1}$, between the temperature of each subsequent reaction zone, T_{SR1} , and the temperature of its immediately preceding reaction zone, T_{IP1} , is less than $+5^{\circ}\text{C}$;

(C) providing a second oxidation reactor comprising a plurality of contact tubes disposed in a reactor shell, the inside of the reactor shell being divided into at least a first heat transfer zone through each of which a heat transfer medium passes; each of said contact tubes containing at least one second oxidation catalyst, said at least one second oxidation catalyst being capable of effecting the

oxidation of said second reactive hydrocarbon and oxygen to a final product gas comprising (meth)acrylic acid, said contact tubes containing at least one second oxidation catalyst being packed with said at least one second catalyst in such a manner so as to provide a peak-to-salt temperature sensitivity of not more than

5 9°C;

(D) feeding said first product gas comprising

- (i) at least one second reactive hydrocarbon, and
- (ii) oxygen

into said second oxidation reactor, at a second reactive hydrocarbon space

10 velocity of from 135 hr⁻¹ to 300 hr⁻¹; to contact said first product gas with said at least one second oxidation catalyst to form a final product gas comprising (meth)acrylic acid;

15 wherein, when each said contact tube of said second oxidation reactor comprises a plurality of sequentially disposed reaction zones, the temperature differential, $T_{SR2} - T_{IP2}$, between the temperature of each subsequent reaction zone, T_{SR2} , and the temperature of its immediately preceding reaction zone, T_{IP2} , is less than +5°C.

3. A catalytic vapor phase oxidation process, comprising :

20 (A) providing an oxidation reactor comprising a plurality of contact tubes disposed in a reactor shell, the inside of the reactor shell being divided into at least one heat transfer zone through which a heat transfer medium passes; each of said contact tubes containing at least one oxidation catalyst, said at least one oxidation catalyst being capable of effecting the oxidation of a reactant

25 composition comprising at least one reactive hydrocarbon selected from the group consisting of acrolein, methacrolein, and mixtures thereof and oxygen into a product gas comprising (meth)acrylic acid, said contact tubes containing at least one oxidation catalyst being packed with said at least one oxidation catalyst in such a manner so as to provide a peak-to-salt temperature sensitivity

30 of not more than 9°C;

(B) feeding a reactant composition comprising

(i) at least one reactive hydrocarbon selected from the group consisting of acrolein, methacrolein, and mixtures thereof, and
(ii) oxygen

into said oxidation reactor, at a reactive hydrocarbon space velocity of from

5 135 hr⁻¹ to 300 hr⁻¹, to contact said reactant composition with said at least one oxidation catalyst to form a product gas comprising (meth)acrylic acid;

wherein, when each said contact tube comprises a plurality of sequentially disposed reaction zones, the temperature differential, TSR - T_{IP}, between the temperature of each subsequent reaction zone, TSR, and the temperature of its
10 immediately preceding reaction zone, T_{IP}, is less than +5°C.

4. A catalytic vapor phase oxidation process, comprising :

(A) providing an oxidation reactor comprising a plurality of contact tubes disposed in a reactor shell, the inside of the reactor shell being divided into at
15 least one heat transfer zone through which a heat transfer medium passes; each of said contact tubes containing at least one oxidation catalyst, said at least one oxidation catalyst being capable of effecting the oxidation of a reactant composition comprising: at least one reactive hydrocarbon selected from the group consisting of propylene, isobutylene, and mixtures thereof and oxygen
20 into a product gas comprising (meth)acrolein, said contact tubes containing at least one oxidation catalyst being packed with said at least one oxidation catalyst in such a manner so as to provide a peak-to-salt temperature sensitivity of not more than 9°C;

(B) feeding a reactant composition comprising

25 (i) at least one reactive hydrocarbon selected from the group consisting of propylene, isobutylene, and mixtures thereof, and
(ii) oxygen

into said oxidation reactor, at a reactive hydrocarbon space velocity of from 135 hr⁻¹ to 300 hr⁻¹ to contact said reactant composition with said at least one
30 oxidation catalyst to form a product gas comprising (meth)acrolein;

wherein, when each said contact tube comprises a plurality of sequentially disposed reaction zones, the temperature differential, TSR - T_{IP}, between the

temperature of each subsequent reaction zone, T_{SR} , and the temperature of its immediately preceding reaction zone, T_{IP} , is less than $+5^{\circ}\text{C}$.

5. A catalytic vapor phase oxidation process, comprising :

5 (A) providing an oxidation reactor comprising a plurality of contact tubes disposed in a reactor shell, the inside of the reactor shell being divided into at least first and second heat transfer zones through each of which a heat transfer medium passes; each of said contact tubes containing at least two sequentially disposed oxidation catalysts, said at least two oxidation catalysts being jointly capable of effecting the oxidation of a reactive hydrocarbon to a product gas comprising (meth)acrylic acid, a first oxidation catalyst in said sequence being capable of effecting the oxidation of a reactive hydrocarbon to (meth)acrolein and being substantially located in that portion of each contact tube in contact with the first heat transfer zone, a second oxidation catalyst in said sequence being capable of effecting the oxidation of (meth)acrolein to (meth)acrylic acid and being substantially located in that portion of each contact tube in contact with the second heat transfer zone; said contact tubes containing said at least two oxidation catalysts being packed with said at least two oxidation catalysts in such a manner so as to provide a peak-to-salt temperature sensitivity of not more than 9°C ; and

20 (B) feeding a reactant composition comprising

- (i) at least one reactive hydrocarbon,
- (ii) oxygen,
- (iii) less than 15 % by volume of the reactant composition of carbon oxides, and

25 (iv) less than 15 % by volume of the reactant composition of inert gas fuel,

with the proviso that the combined amount of carbon oxides and inert gas fuel present in the reactant composition is less than 15 % by volume of the reactant composition,

into said oxidation reactor, at a reactive hydrocarbon space velocity of from 135 hr⁻¹ to 300 hr⁻¹, to contact said reactant composition with said at least two oxidation catalysts to form a product gas comprising (meth)acrylic acid;

wherein, when said portion of each contact tube in contact with the first

5 heat transfer zone comprises a plurality of sequentially disposed reaction zones, the temperature differential, $T_{SR1} - T_{IP1}$, between the temperature of each subsequent reaction zone, T_{SR1} , and the temperature of its immediately preceding reaction zone, T_{IP1} , is less than +5°C;

wherein, when said portion of each contact tube in contact with the

10 second heat transfer zone comprises a plurality of sequentially disposed reaction zones, the temperature differential, $T_{SR2} - T_{IP2}$, between the temperature of each subsequent reaction zone, T_{SR2} , and the temperature of its immediately preceding reaction zone, T_{IP2} , is less than +5°C.

15 6. A catalytic vapor phase oxidation process, comprising:

(A) providing a first oxidation reactor comprising a plurality of contact tubes disposed in a reactor shell, the inside of the reactor shell being divided into at least a first heat transfer zone through each of which a heat transfer medium passes; each of said contact tubes containing at least one first oxidation catalyst, 20 said at least one first oxidation catalyst being capable of effecting the oxidation of a first reactive hydrocarbon and oxygen to a first product gas comprising at least one second reactive hydrocarbon and oxygen, said contact tubes containing at least one first oxidation catalyst being packed in such a manner so as to provide a peak-to-salt temperature sensitivity of not more than 9°C;

25 (B) feeding said first reactant composition comprising

(i) at least one first reactive hydrocarbon, and

(ii) oxygen,

(iii) less than 15 % by volume of the reactant composition of carbon oxides, and

30 (iv) less than 15 % by volume of the reactant composition of inert gas fuel,

with the proviso that the combined amount of carbon oxides and inert gas fuel present in the reactant composition is less than 15 % by volume of the reactant composition,

5 into said first oxidation reactor, at a first reactive hydrocarbon space velocity of from 135 hr^{-1} to 300 hr^{-1} , to contact said first reactant composition with at least one first oxidation catalyst to form a first product gas comprising at least one second reactive hydrocarbon and oxygen;

10 wherein, when each said contact tube of said first oxidation reactor comprises a plurality of sequentially disposed reaction zones, the temperature differential, $T_{SR1} - T_{IP1}$, between the temperature of each subsequent reaction zone, T_{SR1} , and the temperature of its immediately preceding reaction zone, T_{IP1} , is less than $+5^\circ\text{C}$;

15 (C) providing a second oxidation reactor comprising a plurality of contact tubes disposed in a reactor shell, the inside of the reactor shell being divided into at least a first heat transfer zone through each of which a heat transfer medium passes; each of said contact tubes containing at least one second oxidation catalyst, said at least one second oxidation catalyst being capable of effecting the oxidation of said second reactive hydrocarbon and oxygen to a final product gas comprising (meth)acrylic acid, said contact tubes containing at least one second oxidation catalyst being packed with said at least one second catalyst in such a manner so as to provide a peak-to-salt temperature sensitivity of not more than 20 9°C ;

25 (D) feeding said first product gas comprising

(i) at least one second reactive hydrocarbon, and

(ii) oxygen

into said second oxidation reactor, at a second reactive hydrocarbon space velocity of from 135 hr^{-1} to 300 hr^{-1} ; to contact said first product gas with said at least one second oxidation catalyst to form a final product gas comprising (meth)acrylic acid;

30 wherein, when each said contact tube of said second oxidation reactor comprises a plurality of sequentially disposed reaction zones, the temperature differential, $T_{SR2} - T_{IP2}$, between the temperature of each subsequent reaction

zone, T_{SR2} , and the temperature of its immediately preceding reaction zone, T_{IP2} , is less than $+5^{\circ}\text{C}$.

7. A catalytic vapor phase oxidation process, comprising :

- 5 (A) providing an oxidation reactor comprising a plurality of contact tubes disposed in a reactor shell, the inside of the reactor shell being divided into at least one heat transfer zone through which a heat transfer medium passes; each of said contact tubes containing at least one oxidation catalyst, said at least one oxidation catalyst being capable of effecting the oxidation of a reactant
- 10 composition comprising at least one reactive hydrocarbon selected from the group consisting of acrolein, methacrolein, and mixtures thereof and oxygen into a product gas comprising (meth)acrylic acid, said contact tubes containing at least one oxidation catalyst being packed with said at least one oxidation catalyst in such a manner so as to provide a peak-to-salt temperature sensitivity of not more than 9°C ;
- 15 (B) feeding a reactant composition comprising
 - (i) at least one reactive hydrocarbon selected from the group consisting of acrolein, methacrolein, and mixtures thereof,
 - (ii) oxygen,
 - 20 (iii) less than 15 % by volume of the reactant composition of carbon oxides, and
 - (iv) less than 15 % by volume of the reactant composition of inert gas fuel,

25 with the proviso that the combined amount of carbon oxides and inert gas fuel present in the reactant composition is less than 15 % by volume of the reactant composition, into said oxidation reactor, at a reactive hydrocarbon space velocity of from 135 hr^{-1} to 300 hr^{-1} , to contact said reactant composition with said at least one oxidation catalyst to form a product gas comprising (meth)acrylic acid;

- 30 wherein, when each said contact tube comprises a plurality of sequentially disposed reaction zones, the temperature differential, $T_{SR} - T_{IP}$, between the

temperature of each subsequent reaction zone, T_{SR} , and the temperature of its immediately preceding reaction zone, T_{IP} , is less than $+5^{\circ}\text{C}$.

8. A catalytic vapor phase oxidation process, comprising :

- 5 (A) providing an oxidation reactor comprising a plurality of contact tubes disposed in a reactor shell, the inside of the reactor shell being divided into at least one heat transfer zone through which a heat transfer medium passes; each of said contact tubes containing at least one oxidation catalyst, said at least one oxidation catalyst being capable of effecting the oxidation of a reactant
- 10 composition comprising: at least one reactive hydrocarbon selected from the group consisting of propylene, isobutylene, and mixtures thereof and oxygen into a product gas comprising (meth)acrolein, said contact tubes containing at least one oxidation catalyst being packed with said at least one oxidation catalyst in such a manner so as to provide a peak-to-salt temperature sensitivity
- 15 of not more than 9°C ;

(B) feeding a reactant composition comprising

- (i) at least one reactive hydrocarbon selected from the group consisting of propylene, isobutylene, and mixtures thereof, and
- (ii) oxygen,
- 20 (iii) less than 15 % by volume of the reactant composition of carbon oxides, and
- (iv) less than 15 % by volume of the reactant composition of inert gas fuel,

with the proviso that the combined amount of carbon oxides and

- 25 inert gas fuel present in the reactant composition is less than 15 % by volume of the reactant composition,

into said oxidation reactor, at a reactive hydrocarbon space velocity of from 135 hr^{-1} to 300 hr^{-1} to contact said reactant composition with said at least one oxidation catalyst to form a product gas comprising (meth)acrolein;

- 30 wherein, when each said contact tube comprises a plurality of sequentially disposed reaction zones, the temperature differential, $T_{SR} - T_{IP}$, between the

temperature of each subsequent reaction zone, T_{SR} , and the temperature of its immediately preceding reaction zone, T_{IP} , is less than $+5^{\circ}\text{C}$.

9. A catalytic vapor phase oxidation process, comprising :

5 (A) providing an oxidation reactor comprising a plurality of contact tubes disposed in a reactor shell, the inside of the reactor shell being divided into at least first and second heat transfer zones through each of which a heat transfer medium passes; each of said contact tubes containing at least two sequentially disposed oxidation catalysts, said at least two oxidation catalysts being jointly
10 capable of effecting the oxidation of a reactive hydrocarbon to a product gas comprising (meth)acrylic acid, a first oxidation catalyst in said sequence being capable of effecting the oxidation of a reactive hydrocarbon to (meth)acrolein and being substantially located in that portion of each contact tube in contact with the first heat transfer zone, a second oxidation catalyst in said sequence being
15 capable of effecting the oxidation of (meth)acrolein to (meth)acrylic acid and being substantially located in that portion of each contact tube in contact with the second heat transfer zone; said contact tubes containing said at least two oxidation catalysts being packed with said at least two oxidation catalysts in such a manner so as to provide a peak-to-salt temperature sensitivity of not more
20 than 9°C ; and

 (B) feeding a reactant composition comprising

- (i) at least one reactive hydrocarbon,
- (ii) oxygen,
- (iii) less than 15 % by volume of the reactant composition of carbon
25 oxides, and

- (iv) less than 15 % by volume of the reactant composition of inert
 gas fuel,

 with the proviso that the combined amount of carbon oxides and inert gas fuel present in the reactant composition is less than 15 %
30 by volume of the reactant composition,

into said oxidation reactor, at a reactive hydrocarbon space velocity of from 135 hr⁻¹ to 300 hr⁻¹, to contact said reactant composition with said at least two oxidation catalysts to form a product gas comprising (meth)acrylic acid;

wherein, when said portion of each contact tube in contact with the first 5 heat transfer zone comprises a plurality of sequentially disposed reaction zones, the temperature differential, $T_{SR1} - T_{IP1}$, between the temperature of each subsequent reaction zone, T_{SR1} , and the temperature of its immediately preceding reaction zone, T_{IP1} , is greater than +5°C;

wherein, when said portion of each contact tube in contact with the 10 second heat transfer zone comprises a plurality of sequentially disposed reaction zones, the temperature differential, $T_{SR2} - T_{IP2}$, between the temperature of each subsequent reaction zone, T_{SR2} , and the temperature of its immediately preceding reaction zone, T_{IP2} , is less than +5°C.

15 10. A catalytic vapor phase oxidation process, comprising:

(A) providing a first oxidation reactor comprising a plurality of contact tubes disposed in a reactor shell, the inside of the reactor shell being divided into at least a first heat transfer zone through each of which a heat transfer medium passes; each of said contact tubes containing at least one first oxidation catalyst, 20 said at least one first oxidation catalyst being capable of effecting the oxidation of a first reactive hydrocarbon and oxygen to a first product gas comprising at least one second reactive hydrocarbon and oxygen, said contact tubes containing at least one first oxidation catalyst being packed in such a manner so as to provide a peak-to-salt temperature sensitivity of not more than 9°C;

25 (B) feeding said first reactant composition comprising

(i) at least one first reactive hydrocarbon, and

(ii) oxygen,

(iii) less than 15 % by volume of the reactant composition of carbon oxides, and

30 (iv) less than 15 % by volume of the reactant composition of inert gas fuel,

with the proviso that the combined amount of carbon oxides and inert gas fuel present in the reactant composition is less than 15 % by volume of the reactant composition,

5 into said first oxidation reactor, at a first reactive hydrocarbon space velocity of from 135 hr⁻¹ to 300 hr⁻¹, to contact said first reactant composition with at least one first oxidation catalyst to form a first product gas comprising at least one second reactive hydrocarbon, oxygen, carbon oxides and inert gas fuel ;

10 wherein, when each said contact tube of said first oxidation reactor comprises a plurality of sequentially disposed reaction zones, the temperature differential, $T_{SR1} - T_{IP1}$, between the temperature of each subsequent reaction zone, T_{SR1} , and the temperature of its immediately preceding reaction zone, T_{IP1} , is greater than +5°C;

15 (C) providing a second oxidation reactor comprising a plurality of contact tubes disposed in a reactor shell, the inside of the reactor shell being divided into at least a first heat transfer zone through each of which a heat transfer medium passes; each of said contact tubes containing at least one second oxidation catalyst, said at least one second oxidation catalyst being capable of effecting the oxidation of said second reactive hydrocarbon and oxygen to a final product gas comprising (meth)acrylic acid, said contact tubes containing at least one second oxidation catalyst being packed with said at least one second catalyst in such a manner so as to provide a peak-to-salt temperature sensitivity of not more than 20 9°C;

25 (D) feeding said first product gas comprising

- (i) at least one second reactive hydrocarbon,
- (ii) oxygen,
- (iii) carbon oxides, and
- (iv) inert gas fuel

20 into said second oxidation reactor, at a second reactive hydrocarbon space velocity of from 135 hr⁻¹ to 300 hr⁻¹; to contact said first product gas with said at least one second oxidation catalyst to form a final product gas comprising (meth)acrylic acid;

wherein, when each said contact tube of said second oxidation reactor comprises a plurality of sequentially disposed reaction zones, the temperature differential, $T_{SR2} - T_{IP2}$, between the temperature of each subsequent reaction zone, T_{SR2} , and the temperature of its immediately preceding reaction zone, T_{IP2} , is greater than $+5^{\circ}\text{C}$.

5 11. A catalytic vapor phase oxidation process, comprising :

(A) providing an oxidation reactor comprising a plurality of contact tubes disposed in a reactor shell, the inside of the reactor shell being divided into at least one heat transfer zone through which a heat transfer medium passes; each of said contact tubes containing at least one oxidation catalyst, said at least one oxidation catalyst being capable of effecting the oxidation of a reactant composition comprising at least one reactive hydrocarbon selected from the group consisting of acrolein, methacrolein, and mixtures thereof and oxygen into a product gas comprising (meth)acrylic acid, said contact tubes containing at least one oxidation catalyst being packed with said at least one oxidation catalyst in such a manner so as to provide a peak-to-salt temperature sensitivity of not more than 9°C ;

10 (B) feeding a reactant composition comprising

15 (i) at least one reactive hydrocarbon selected from the group consisting of acrolein, methacrolein, and mixtures thereof,

20 (ii) oxygen,

25 (iii) less than 15 % by volume of the reactant composition of carbon oxides, and

(iv) less than 15 % by volume of the reactant composition of inert gas fuel,

with the proviso that the combined amount of carbon oxides and inert gas fuel present in the reactant composition is less than 15 % by volume of the reactant composition,

30 into said oxidation reactor, at a reactive hydrocarbon space velocity of from 135 hr^{-1} to 300 hr^{-1} , to contact said reactant composition with said at least one oxidation catalyst to form a product gas comprising (meth)acrylic acid;

wherein, when each said contact tube comprises a plurality of sequentially disposed reaction zones, the temperature differential, $T_{SR} - T_{IP}$, between the temperature of each subsequent reaction zone, T_{SR} , and the temperature of its immediately preceding reaction zone, T_{IP} , is greater than $+5^{\circ}\text{C}$.

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12. A catalytic vapor phase oxidation process, comprising :

(A) providing an oxidation reactor comprising a plurality of contact tubes disposed in a reactor shell, the inside of the reactor shell being divided into at least one heat transfer zone through which a heat transfer medium passes; each 10 of said contact tubes containing at least one oxidation catalyst, said at least one oxidation catalyst being capable of effecting the oxidation of a reactant composition comprising: at least one reactive hydrocarbon selected from the group consisting of propylene, isobutylene, and mixtures thereof and oxygen into a product gas comprising (meth)acrolein, said contact tubes containing at 15 least one oxidation catalyst being packed with said at least one oxidation catalyst in such a manner so as to provide a peak-to-salt temperature sensitivity of not more than 9°C ;

(B) feeding a reactant composition comprising

20 (i) at least one reactive hydrocarbon selected from the group consisting of propylene, isobutylene, and mixtures thereof,
(ii) oxygen,
(iii) less than 15 % by volume of the reactant composition of carbon oxides, and
(iv) less than 15 % by volume of the reactant composition of inert 25 gas fuel,
with the proviso that the combined amount of carbon oxides and inert gas fuel present in the reactant composition is less than 15 % by volume of the reactant composition,
into said oxidation reactor, at a reactive hydrocarbon space velocity of from 30 135 hr^{-1} to 300 hr^{-1} to contact said reactant composition with said at least one oxidation catalyst to form a product gas comprising (meth)acrolein;

wherein, when each said contact tube comprises a plurality of sequentially disposed reaction zones, the temperature differential, $T_{SR} - T_{IP}$, between the temperature of each subsequent reaction zone, T_{SR} , and the temperature of its immediately preceding reaction zone, T_{IP} , is greater than $+5^{\circ}\text{C}$.